PROGRESS REPORT

TO

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

ON

CONTRACT NO. NASr-82

CONSTRUCTION OF A 60-INCH LUNAR AND PLANETARY TELESCOPE

April 1 - December 31, 1965

by

Gerard P. Kuiper

Lunar and Planetary Laboratory

University of Arizona

Tucson, Arizona

9 March 1966

Progress Report on NASA 61-inch Telescope

April 1-December 31, 1965

Gerard P. Kuiper

The 61-inch telescope was assembled on June 18 and tested on stars. A number of weak spots were discovered and we worked diligently during the months of July and August to improve the instrument. One aspect involved the support system. The design used by our staff was based on the system developed at the University of Chicago for the McDonald 82-inch in the middle 1950's, with Dr. Meinel, then of the University of Chicago staff, contributing most of the ideas. The system had more friction than desirable, and certain units were replaced by ballbearings. The system was complete about mid-August and has been thoroughly tested. It is very sensitive now and almost frictionless, and we are completely satisfied with it.

Another aspect was the telescope frame itself, constructed at Western Gear Company, Los Angeles. They had been careless in sand-blasting operationswhich preceded putting on the coat of paint. Sand had entered holes drilled for the wiring and had remained in the frame. This sand began to pour when the instrument was operated at extreme angles east and west. It was removed with considerable difficulty because of the almost inaccessible spaces where the sand had lodged itself. The cleaning operation by LPL was completed a few weeks later but it required disassembling the mirror support system and other units where some sand had entered. These operations were completed satisfactorily. On September 1, Dr. Kuiper made tests with the newly-assembled equipment, and it was clear that very large progress had been made since June in ironing out the various small difficulties that had come up and in making the necessary adjustments. Because the rainy season was not yet over, it was decided to finish the checking and improvement program during September so that observing time would not be lost in favorable climatic conditions, starting around October 1.

The remaining work on the lesser mechanical items still requiring attention was carried out with all possible dispatch, with Mr. Sam Case, our design engineer, and his staff often working seven days a week and twelve or more hours a day to accelerate the program. The scientific staff was on hand for tests whenever needed. This program of intensive finishing up was essentially completed on October 7, 1965.

With the assistance of staff members and our chief optician, we examined the image closely on that night and regarded it satisfactory. There were still a few residual mechanical troubles, one being with the clutches used in the right ascension and declination drives which appeared to be too weak and which prevented us from using preloads on the drives that were sufficiently powerful to minimize telescope shake in the presence of strong winds. These clutches were later replaced but did not prevent us from starting scientific observations on October 8, 1965. The completed telescope is shown in Figures 1 and 2, the latter showing the support system exposed.

Sixteen plates, 5 x 7 inches each, of the moon were obtained at the F/45 focus (scale 3 arc seconds per millimeter) on October 8 of which about half were already of "research quality," which means comparable to, or better than, the best plates of the moon obtained before of the areas and illuminations observed. On October 9, forty-one plates of the moon were obtained at the same focus of which nearly all were of research quality. No lunar observations were possible on October 10, but on October 11 twelve further plates were obtained, with the majority being of research quality. October 13 was an excellent night during which we obtained seventy plates of the moon, all of them of research quality and about half of superior quality with resolutions of about 0.2 arc seconds or better. A number of mediocre or poor nights followed during which no good lunar photography was possible. The program was resumed October 19.

Since that time the telescope has been in constant use (weather permitting) with lunar and planetary photography 50% of the time and the balance of the time for spectroscopy, polarization, IR and UV photography, double stars, Uranus satellites, visual observations and stellar photometry. To date we have obtained 985 plates of the moon, 5 x 7 inches each, of which about 250 are of excellent quality (some prints have been sent). A graph showing the quality distribution of the lunar plates is reproduced in Figure 3. It must be noted that these observations were made during the wettest winter on record in the SW, when practically no observations could be made at the California observatories. Our previous tests have shown the winter image quality to be the worst of the year.

Our experience with the 61-inch can be compared with that of two other large telescopes, the 82-inch at McDonald and the 84-inch at Kitt Peak. The 82-inch at McDonald required only about two weeks of testing before it was considered operational, but it took four years for its completion, and it was built at a much greater expense and not partly "in house" as our own instrument. Even so, the telescope was not fully effective until the support system was completely rebuilt in the Yerkes shops in the middle 1950's, something which lasted approximately a year; and the Coudé spectrograph was completely revamped, something that took four years. Finally, the optics of the 82-inch were reworked by Mr. Texereau in 1964; and, therefore, twenty-five years after the installation of the 82-inch, it can now be finally regarded as optimized. The Kitt Peak 84-inch has been about six years under construction, and after astronomers interested in using the equipment thought it was complete, it took approximately nine months to correct the various flaws discovered during its test period. The cost of the Kitt Peak 84-inch was about $1.9 million; the total cost of the 61-inch NASA telescope so far has been about $345,000, and the construction and test time so far have been about two years (buildings $680,000 and 200,000).

As I have mentioned in correspondence and letter reports, we felt quite certain that optimum image resolution with the 61-inch NASA telescope would require the addition of a third cage as an alternate to the F/13.5 and F/45 cages and optics, already in existence. This third cage would contain a plane parallel optical transparent flat plate which would in effect close in the tube and produce thermal conditions within the telescope, resembling those found in a refractor. This would produce diffraction-limited optics under thermally stable conditions.

We had four options in the nature and dimension of this plane parallel plate: (1) UV optics; (2) Crown glass optics; used either at full aperture, about 62 inches, to avoid vignetting; or a smaller aperture, to reduce atmospheric seeing troubles, cost of production, time and weight. After very careful consideration, we have selected 45-inch aperture and UV glass. This aperture will give a diffraction disk of precisely 0.1 arc seconds in yellow light, which is the best we can hope for under all but very exceptional conditions. By using blue-violet light (4400 A), the diffraction disk can be made 0.08 arc sec. With the reduced aperture we shall have better seeing, and it will greatly simplify the problem for the optician of making a completely satisfactory optical plate (plane parallel optical plates are much more difficult to produce than spherical surfaces). Funds were still available in the NASA contract to cover this expenditure and the optical work plus the construction of the mechanical mounting of the third cage.

In addition to the lunar plates, we have obtained 835 films, 35 mm, of Jupiter; and 248 films, 35 mm, of Saturn. Many of these are in color and show a range in color values on these planets.

Dr. Low has made very important observations of the planets Saturn, Jupiter, Venus, and of several stars at 10 and 20 microns. The humidity of the atmosphere had dropped enough to open up the 20-micron window which is closed at nearly all U. S. observatories because of the much greater humidity. Results of singular importance have been obtained. One is that the planet Jupiter radiates more heat of internal origin than the amount absorbed from the sun and reradiated in the infrared. The ratio appears to be 2 or 2 1/2 to 1. He has also obtained drift curves at 20 microns of these planets across their disks both EW and NS, which gives information on the vertical structure of these atmospheres. The belts of Jupiter stand out at 20 μ for their different temperatures, a most significant result for the interpretation of the condensation products and colors.

We have furnished U.S.G.S. in Palo Alto with approximately 100 contact lunar positives and ACIC-Lowell a number of enlargements on paper.

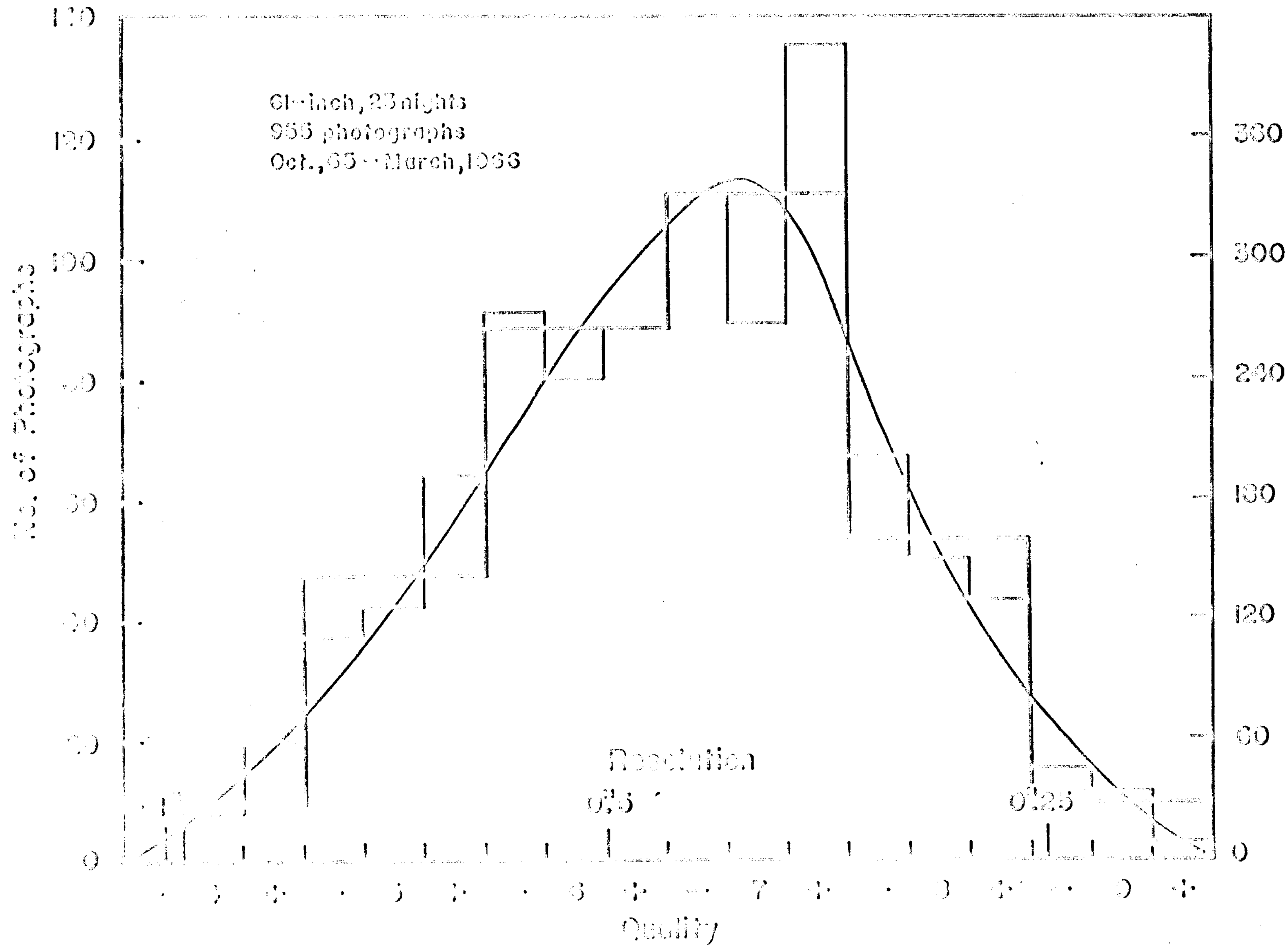
The dome and building (Figure 4) were provided by the University of Arizona to house the 61-inch NASA telescope. The lower floor contains a lounge equipped with kitchen and some modest overnight accommodations, a washroom, a well-equipped darkroom, the main electric switchboard, a 2000 gal. water storage tank, storage space, and a loading shaft with trap door in the ceiling for moving heavy equipment to the observing floor. The observing floor, in addition to the piers and telescope, has a moving platform at the center for all normal astronomical operations. On the platform is located a 2-cabinet console and control. The dome shutters move sideways on tracks, as rolling doors, which has the advantage of allowing reduced slit widths for daytime operations (keeping out sunlight). Both upper and ~~lower~~ wind curtains are provided over the slit. The dome revolves exceptionally smoothly, its track having been inclined with the proper angle for conical motion of the wheels. The dome has its own sewage disposal unit. The water tank is at present filled by truck but eventually we hope to connect it with a spring outside the observatory property. I am completely satisfied with the building, and experience to date has shown that its thermal properties are as favorable as anticipated. In particular, the fact that the dome has been painted with titanium-dioxide white paint has had the desired effect of keeping the daytime temperature in the building low and making the dome cold at night, which causes the air in contact with it to descend, leaving the air in the optical path in front of the telescope the undisturbed ambient atmosphere. My personal experience and that of our other observers has consistently been that "dome seeing" and "telescope seeing" are remarkably small and that the limit of resolution in the photographic image is almost entirely set by the atmospheric disturbances in the free atmosphere above the dome. I have personal experience with all the large telescopes in the U. S. except the Lick 120-inch and believe it is fair to say that we have succeeded unexpectedly well in minimizing thermal effects within telescope and dome.

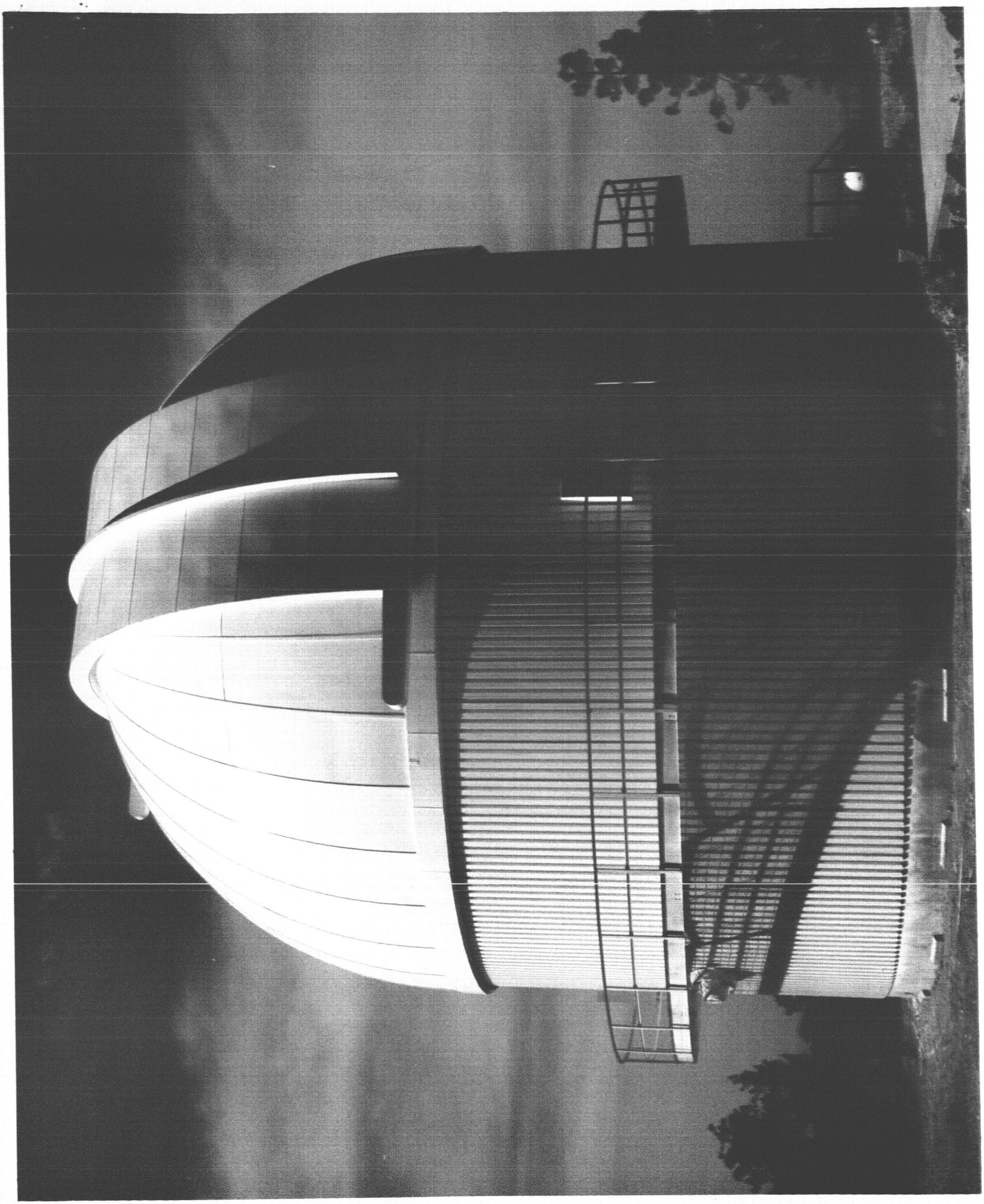
As previously stated, we have still to complete the third cell for the 61-inch telescope and its 45-inch plane-parallel optical plate. The blank for the plate was ordered in September 30, 1965, and the plate is due late March 1966. We have also made provision for a spectrograph attachment that has not yet been fully designed and will not be completed until late 1966.

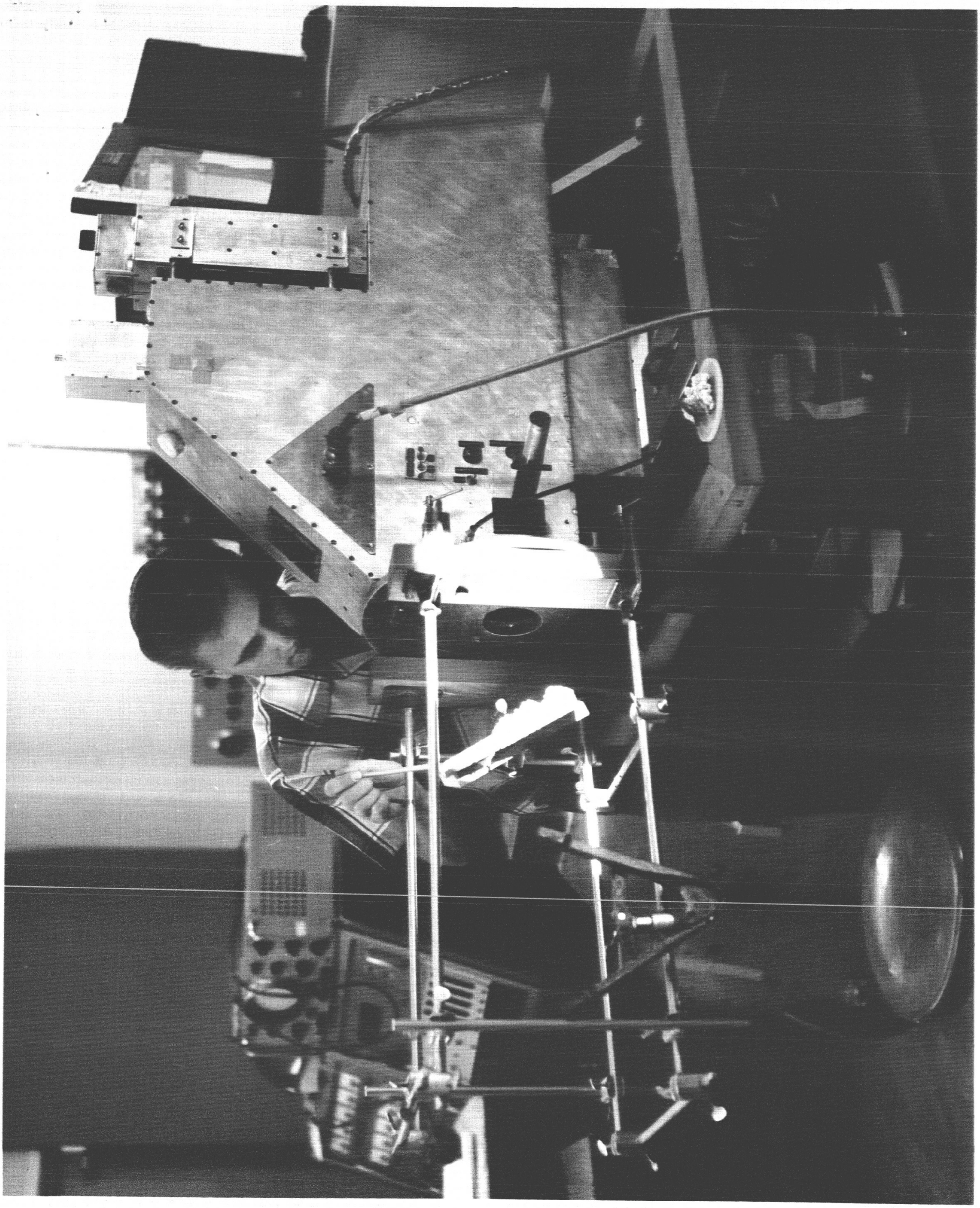
As an astronomer, I am completely satisfied with the results achieved to date. The optics, good to 1/40th of a wave, are better than those of any other large telescope. When the atmosphere is steady, images of the moon and of the planets are remarkably crisp and free from distortions. We have been able to observe the spots on the satellites of Jupiter in much greater detail than I have ever been able to observe them with the 82-inch telescope in Texas. We have an excellent instrument, but certain additions and improvements can and must still be made. In addition to the third cage and the high-dispersion spectrograph, we need to develop a camera that triggers only when the seeing is excellent to take advantage of the best moments of seeing (see Figure 3) without the need of taking a very large number of plates of lesser quality. (Based on earlier visual tests, during the best six months of the year the entire curve of Figure 3 will be displaced to the right. Nevertheless, one is still interested only in the high-resolution part.)

At present we have the following working attachments: (1) 5 x 7 plateholder for lunar photography, (2) planetary enlarging camera, (3) 35 mm planetary camera, (4) low-dispersion spectrograph (with 340A/mm and 2000A/mm cameras), (5) medium-dispersion grating spectrograph (Fig. 5), (6) medium-resolution IR spectrometer (Fig. 6), (7) various multicolor automatic photometers built by Dr. H. Johnson, (8) polarimeter built by Dr. T. Gehrels, (9) IR scanning devices built by Dr. F. Low.

Dr. T. L. K. Smull, Grants Administrator of NASA, and Dr. William Brunk of the Office of Lunar and Planetary Sciences, visited the University on October 22 and participated in the dedication of the telescope. A copy of my comments made at the luncheon is herewith appended.


No. of Photographs
955 photographs
Oct., 65 - March, 1966
Resolution
0.5
0.25
Quality
300
240
180
120
60
0





Dr. Smull, Dr. Brunk, President Harvill,

Distinguished guests and friends:

As a spokesman for the scientists who will use the Space Sciences Building, I welcome the opportunity to make a few comments. The scientists at the University of Arizona interested in space-related investigations look upon the Space Sciences Building as a center for collaboration and for important new research.

The advances in the natural sciences, particularly planetary and lunar astronomy, geophysics in the broad sense, the investigation of the radiation belts surrounding the earth, and the plasma clouds blowing from the sun through the interplanetary space; all of these subjects have gained immeasurably from the large programs initiated by NASA. Also, the supporting technology is taking on completely new forms. The methods of investigation available to the scientist today are so much more powerful than those used only one or two decades ago, that we can speak truly of the birth of Space Science having occurred in the past decade.

University facilities have been able to keep up with much of this explosive development only through direct participation in the NASA programs. The Space Sciences Building on this Campus is dedicated to this proposition. Through it and with the facilities expected to be created in it, we hope to be able to make our contribution in the physical sciences during this remarkable period of history.

As you know, the facilities of this Building will be used by several departments:

Aerospace and Mechanical Engr.
Astronomy
Chemical and Metallurgical Engr.
Geology
Lunar and Planetary Laboratory
Meteorology
Physics
Psychology

It is not possible on this occasion to do justice to the careful plans laid by these departments for research in the Space Sciences Building during the coming several years. Let me list just a few.

The Lunar and Planetary Laboratory will be re-united in the Building, after its present operations are distributed over three buildings in Tucson, one on the Campus and two in the city. Its main programs will continue to be lunar and planetary photography; high-resolution spectroscopic investigations of planetary atmospheres both in the visual and in the infrared; infrared scans (heat maps) of the moon to longer and longer wave lengths, with apparatus for 20 microns being developed by Dr. Low for use during the coming winter; infrared detector development by Dr. Low, with advances of approximately 100 in sensitivity already being achieved between 1 and 2 microns; precision filter photometry in numerous wave length bands from the ultraviolet to the far infrared by Professor Harold Johnson; a massive program on the Orbiting Astronomical Observatory under the joint direction of Drs. Johnson and Gehrels; a high-altitude balloon program (Project Polariscope) directed by Dr. Gehrels; the development of an absorption tube with a very long path, 8 or 10 km, under the direction of Dr. Toby Owen, for simulated studies of planetary atmospheres; an extensive program of lunar cartography and an up-dating of lunar nomenclature, with close coordination with the International Astronomical Union which has entrusted our group with this program; close liaison with the Air Force lunar mapping program at Flagstaff, under NASA sponsorship; geological field studies related to the program of lunar exploration; and important editorial programs in the production of the two major handbooks in astronomy being produced during this decade, the 5-volume series "The Solar System," and the 9-volume series "Stars and Stellar Systems," under the overall editorship of Miss Barbara Middlehurst and myself.

Very significant programs are being carried out at the Institute of Atmospheric Physics. Dr. Herman will conduct laboratory studies of dust in the Mie region with an experimental program and supported by theoretical computations. His work has already been widely used at Kitt Peak, CalTech, and LPL. Dr. Staley has collaborated with Dr. Owen of LPL on the dynamics of the Jupiter atmosphere and other programs. The site of the Catalina Station is being used during the summer periods, when heavy rains occur, for a pulse Doppler investigation of rain drops from which the meteorologists are deriving important information on the dynamics of clouds. These results have a general bearing on the dynamics of planetary atmospheres and the formation of condensation products.

The participation of the Physics Department in the Space Sciences Building will include a Cryogenic program carried out jointly with Professor Frank Low. This is an essential component of infrared detector development which requires very low temperatures for optimum use. Also, included will be analysis of Dr. Bashkin's accelerator program (optical and ultraviolet spectra obtained by bombardment of 2 meV ions).

The geological program will include lunar stratigraphic mapping, magnetic studies of meteorites and mapping of volcanic terrain. A very promising program in astronomy will consist of the development of a UVA spectrograph for Project Apollo and the development of further apparatus for its extensions.

I should like to endorse the comment made by President Harvill on the importance to the scientists at the University of the proximity of the Kitt Peak National Observatory. We have enjoyed the best relations with Director Mayall and the staff of the National Observatory, and have tremendously benefited from the use of their facilities on the mountain and from the assistance received through the staff. We are looking forward to a closer cooperation and integration of our efforts after our move to the Space Sciences Building, which will bring us adjacent to the Tucson offices of the National Observatory.

I should like to pay tribute also to the Architect of the Space Sciences Building, Mr. William Wilde, who is also the architect of our buildings at the Catalina Station. We appreciate the efforts he has made and continues to make to interpret our scientific and operational needs into inexpensive and functional buildings, which are pleasing in appearance and possess quality.

In conclusion, I should like to make a few remarks on the 61-inch telescope to be dedicated this afternoon at our Catalina Station. NASA has funded a 60-inch telescope, but we managed to stretch it to 60.8 which we round off to 61. Mr. Robert Waland has produced optics of unsurpassed quality in a period of only about one year. The primary mirror is accurate to a fortieth of a wave. I want to express my appreciation and thanks also to Mr. Sam Case who was in charge of the design of the telescope and mounting, carried out with great skill and diplomacy our relations with Western Gear Company, and has worked so hard in the last three months during the period after the installation of the telescope to remove remaining weaknesses in concept or structure. We now have an excellent instrument, although it must be recognized that further refinements will undoubtedly be needed; and in any case, a third cage still needs to be constructed which will house a 45-inch plane-parallel optical plate of ultraviolet glass. This third cage will be used with the tube enclosed with insulating material in an effort to obtain the ultimate in resolution, of which the telescope should be capable, one-tenth arc seconds or about 600 feet on the moon. We have contended all along that this goal is achievable from an earth-based observatory, and I am very pleased to announce that already in the past two weeks of operation we have achieved a gain of resolution over the Photographic Lunar Atlas by a factor between 2 and 3. We have approached the ultimate limit of the instrument by a factor of 2 now, the photographic resolution achieved being 0.2 arc seconds. We are reasonably confident that with further effort we shall be able to reach the goal.

I want to express my thanks also to Mr. Nasmyth, Vice President of Western Gear Company, for the efforts his Company have made to produce a good mounting and a very excellent right ascension gear. It is fitting that the first telescope built under Mr. Nasmyth's direction should be used for lunar studies, his great-great grandfather James Nasmyth, C. E., being the co-author, with James Carpenter, F.R.A.S., of the famous 19th century book, "The Moon," a copy of which I treasure on my shelves.

In conclusion, I would like to express my thanks to Mr. Clyde Doran, Regional Supervisor of the Coronado National Forest (Southern Arizona) and his staff for their interest in our Catalina Station. We are there the guests of the U. S. Forest Service and we appreciate their friendly understanding of our scientific needs.